

QCALT: a tile calorimeter for KLOE-2 experiment

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Abstract

The upgrade of the DAΦNE machine layout requires a modification of the size and position of the inner focusing quadrupoles of KLOE-2 thus asking for the realization of two new calorimeters covering the quadrupoles area. To improve the reconstruction of $K_L \rightarrow 2\pi^0$ events with photons hitting the quadrupoles a calorimeter with high efficiency to low energy photons (20-300 MeV), time resolution of less than 1 ns and space resolution of few cm, is needed. To match these requirements, we are designing a tile calorimeter, QCALT, where each single tile is readout by mean of SiPM for a total granularity of 2400 channels. We show first tests of the different calorimeter components.

Key words: Kloe-2, Calorimeters, SiPM, tiles, WLS fibers.

1. The KLOE-2 proposal

In the last decade a wide experimental program has been carried out at DAΦNE[1], the e^+e^- collider of the Frascati National Laboratories, running at a center of mass energy of the ϕ resonance. During KLOE[2] run, DAΦNE delivered a peak luminosity of $1.5 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$ (corresponding to 1 fb^{-1} per year).

A new machine scheme[3] has been recently proposed to increase the luminosity of the machine up to a factor 5. This scheme has been successfully tested at DAΦNE, and the encouraging results pushed for a new data taking campaign. This new phase will start a new experiment, named KLOE-2, aiming to complete KLOE physics program.

To improve the performances of the detector we expect to add new subdetector systems such as: an inner tracker, a tagger system to study $\gamma\gamma$ physics, a new small angle calorimeter and a new quadrupole calorimeter. In this paper we explain the project and R&D for this last detector.

2. The quadrupole tile calorimeter, QCALT

In the old IP scheme of DAΦNE the inner focalizing quadrupoles have two surrounding calorimeters QCAL [4] covering a polar angle down to 21 degrees. Each calorimeter consists of 16 azimuthal sectors composed by alternating layers of 2 mm lead and 1 mm BC408 scintillator tiles, for a total thickness of $\sim 5 X_0$. The fiber arrangement (back bending) allows the measurement of the longitudinal coordinate by time differences with a resolution of 13 cm. These calorimeters are characterized by a low light response (1-3 pe/mip/tile) due to the coupling in air, to the fiber length ($\sim 2 \text{ m}$ for each tile) and to the quantum efficiency of the used photomultipliers (standard bialkali with $\sim 20\%$ QE).

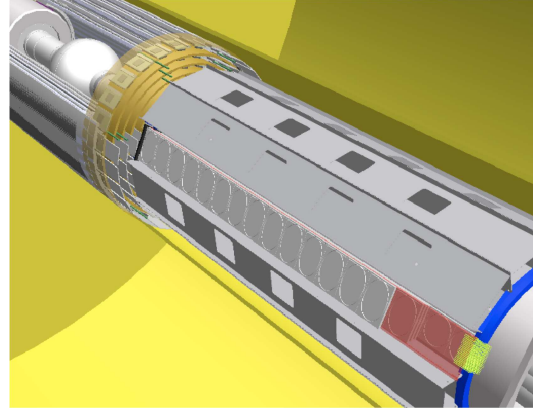


Figure 1: IP scheme of KLOE-2. In this project are visible the inner tracker around IP and QCAL surrounding quadrupoles.

The project of the new QCAL (See Fig.1) consists in a dodecagonal structure, 1 m long, covering the region of the new quadrupoles composed by a sampling of 5 layers of 5 mm thick scintillator plates alternated with 3.5 mm thick tungsten plates, for a total depth of 4.75 cm ($5.5 X_0$). The active part of each plane is divided into twenty tiles of $\sim 5 \times 5 \text{ cm}^2$ area with 1 mm diameter WLS fibers embedded in circular grooves. Each fiber is then optically connected to a silicon photomultiplier of 1 mm^2 area, SiPM, for a total of 2400 channels.

We report the R&D studies done on SiPM, fibers and tiles we have carried out to select the components which optimize the performance of our system.

2.1. Tests performed on single components

We have compared the characteristics of two different SiPM produced by Hamamatsu (multi pixel photon

counter, MPPC): 100 (S10362-11-100U) and 400 pixels (S10362-11-050U), both with $1 \times 1 \text{ mm}^2$ active area.

We have prepared a setup based on a blue light pulsed LED, a polaroid filter to modify the light intensity and a SiPM polarization/amplification circuit based on Mini-circuits MAR8-A+ amplifier. We have measured the gain and the dark rate variation as a function both of the applied V_{bias} and the temperature of the photodetector. The readout electronics was based on CAMAC, with a charge sensitivity of 0.25 pC/count and a time of 125 ps/count.

Our tests confirm the performances declared by Hamamatsu and show a significative variation of the detector gain as a function of the temperature (3% for 400 pixels versus 6% for 100 pixels).

To decide the best fiber solution, we have studied the light response of two different, 1 mm^2 , WLS from blue to green, fibers optically connected to MPPC when hit by electrons produced by a Sr^{90} source: Saint Gobain BCF92 single cladding and Saint Gobain BCF92 multi cladding. The adopted solution is Saint Gobain BCF92 multi cladding. For this fiber we find, as expected, a large light yield than the one with single cladding ($\times 1.5$), a fast emission time (5 ns/pe) and long attenuation length.

Light response and time resolution of a complete tile have been measured using cosmic rays. The system was prepared connecting fiber to MPPC and using two external NE110 scintillators fingers to trigger the signal. We have prepared different tiles (3 and 5 mm thick) readout with 100 or 400 pixels MPPC. The adopted solution is 5 mm thick BC408 tile readout by 400 pixels MPPC which balance the light yield optimization versus the dark rate. For this system we obtain 32 pe/mip with a time resolution of 750 ps after correcting for the time dependence on pulse height.

Controlling enviromental conditions and using LED light, we have also studied SiPM response when varying V_{bias} . By using the photon counting properties of the SiPM we observe an increase of the light yield when increasing V_{bias} as shown in Fig.2. The device reach a plateau 600 mV above operatin voltage, which is consistent with a variation of the photon detection efficiency of the SiPM for the avalanche probability.

2.2. FEE electronic

To manage the signals for many channels, the electronic service of the Frascati Laboratory has developed some custom electronics composed by a $1 \times 2 \text{ cm}^2$ chip, containing the pre-amplifier and the voltage regulator, and a multi-function NIM board. The NIM board supplies the V_{bias} to the photodetector with a precision of 2 mV and a stability at the level of 0.03 permill. A low threshold discriminator and a fanout are also present.

2.3. Next plans

We are now assembling two small dimension prototypes of the QCAL (two full planes with 20 tiles/each and one

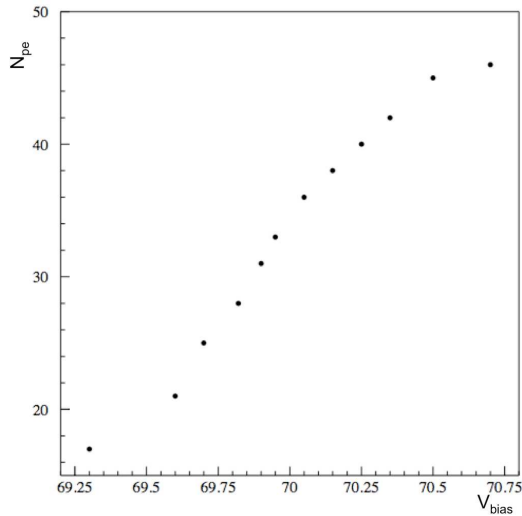


Figure 2: Signal detected by SiPM using a fixed LED light and varying V_{bias} .

full column with 5 planes) , to study both the signal transportation to the end and to measure the effective radiation length at electron beam. For the end of 2009, we plan also to construct a “module 0” consisting of a complete slice of the dodecagon ($1/12^{th}$ of one calorimeter) with final material and electronics.

3. Conclusions

The new scheme proposed for DAΦNE machine allows a factor 5 increase in the delivered luminosity. Some R&D are in progress to add new components to the KLOE apparatus. We have presented the project and the R&D in progress for a tile calorimeter surrounding the focalizing quadrupoles. Using $5 \times 5 \times 0.5 \text{ cm}^3$ BC408 tile, readout by 400 pixels MPPC, we obtain 32 pe/mip with a time resolution of 750 ps.

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